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ABSTRACT

This study used a sociolinguistic and micro-ethnographic approach to examine whether the setting of a mathematics task had an impact on the type and quality of classroom discourse, and it described the teacher's conflicts and resolutions in facilitating student discourse in a sixth-grade mathematics classroom. Data collection occurred from January to February of 1997. Twelve students in a suburban Maryland elementary school participated. The students were presented with three 2-week units over the 6-week study. They worked in groups of four and were switched to different small groups after each unit was taught. They applied their mathematical knowledge to complete hands-on geometry investigations. The researcher videotaped students as they performed activities in each of three task settings: applied, integrated, and abstract. The students completed three interviews (one after each unit). Data analysis examined students' participating behaviors and factors influencing the amount and quality of student discourse. Results found five types of participating behavior (giving information, asking or requesting information, directing others, helping others, and agreeing or disagreeing with others). Teacher variables significantly influenced the types of participating behavior. Variables included teacher pedagogical content knowledge, teacher questioning strategies, use of instructional strategies, and classroom norms. The quality of student discourse depended on the background knowledge students could apply to the task. (Contains 21 references.) (SM)

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When the Task is not Just a Task:

What One Mathematics Teacher Learned About Facilitating Student Discourse

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WHEN THE TASK IS NOT JUST A TASK:

What One Mathematics Teacher Learned About Facilitating Student Discourse

Abstract. This study used a sociolinguistic and micro-ethnographic approach to examine the types of participating behavior and to determine the quality of student discourse that emerged around a variety of tasks in a sixth-grade mathematics class. The data was collected at one elementary school in suburban Maryland over a six-week period from January to February 1997. Twelve target students were videotaped as they performed activities in each of three task settings—applied, integrated and abstract—and were interviewed following each task. Qualitative research methods were used to analyze this data. The findings show that teacher variables have a great deal of influence on the types of participating behavior, and the quality of student discourse is dependent upon the background knowledge students can apply to the task.

WHEN THE TASK IS NOT JUST A TASK:

What One Mathematics Teacher Learned About Facilitating Student Discourse

"There are two aspects to providing occasions for wonderful ideas. One is being willing to accept children's ideas. The other is providing a setting that suggests wonderful ideas to children—different ideas to different children—as they are caught up in intellectual problems that are real to them" (Duckworth, 1996, p. 7).

Introduction

One can hardly begin a conversation about improving mathematics education without referring to the National Council of Teachers of Mathematics' *Standards* (NCTM, 1989, 1991, & 1995). These documents provide a vision of what curriculum, pedagogy, and assessment should be. However, the *Standards* offer teachers no panacea. Recommendations such as using technology and real-world applications are difficult to implement because of teachers' limited time, background knowledge and resources, and facilitating classroom discourse creates tension because students' opinions are not always universal.

Many school districts across the nation have adopted the *Standards* and expect teachers to comply with them, but exactly how teachers implement the *Standards* and engage students in meaningful but cost effective tasks remains illusive for many teachers, especially urban mathematics teachers. If measurable change is to occur, some believe reform must take place on a grassroots level in everyday classrooms.

Teaching is a complex enterprise (Shulman, 1987), and teaching standards-based mathematics presents certain challenges. First, choosing the mathematical task ultimately determines what mathematics content the students will learn. Second, selecting the task setting determines the contextual experience that students will have. Third, using mathematical tasks as

a springboard to facilitate classroom discussions implies that teachers have a repertoire of questioning strategies. However, dilemmas may emerge if teachers do not have the pedagogical content knowledge to guide student discussions in purposeful directions (Shulman, 1987).

Teaching dilemmas and instructional practice have been the focus of several teacher-research studies (Ball, 1993; Lampert, 1989). Teacher research allows classroom teachers to tell their own stories and to reflect and improve on their practice (Cochran-Smith & Lytle, 1990). The purpose of this paper is two-fold. First, the paper examines whether the setting of the mathematics task has an impact on the type and quality of classroom discourse. Second, it describes my own conflicts and resolutions in facilitating student discourse in a sixth-grade mathematics classroom.

Theoretical Framework

In reform-based classrooms, learning is viewed from a social constructivist perspective (Fuson, 1996), and the sociolinguistic paradigm has provided the framework for teacher-researchers to offer rich descriptions of their experiences (Eisenhart, 1988). Expert teachers possess a wealth of subject-matter knowledge and use inductive questioning strategies to guide classroom discussions (Borko & Livingston, 1989). This paper reports on a micro-ethnographic and sociolinguistic study that examines mathematical tasks and classroom discourse. A narrative is told about my own experience as an expert teacher and a novice researcher to engage students in mathematical discussions.

Research Questions

The first two research questions guided the initial inquiry. After the data was collected, question three emerged.

(1) How does the type of participating behavior compare and contrast when target students engage in learning tasks within applied, integrated and abstract settings?

(2) What quality of discourse emerges when differentiated tasks—geometric and structural models, making and using weather-related instruments, and performing simple operations on matrices—are presented to students?

(3) What can teachers learn about facilitating classroom discourse as a result of presenting students with a variety of activities?

Definitions

Participating behavior is defined as the type of discourse as well as the social behaviors that students exhibit as they interact with one another (Mulryan, 1995). Mathematical discourse is defined as "purposeful talk on a mathematical subject in which there are genuine contributions and interaction" (Pirie & Schwarzenberger, 1988, p. 461). The quality of the student discourse is defined as the substance or content of the mathematical conversations in which the students engage (Leonard, 1997). The task settings are described as follows: (1) students apply their mathematical knowledge to real-world problems in an applied setting; (2) students integrate knowledge in other content areas with mathematics in an integrated setting; and (3) students use words, numbers and/or symbols to solve problems in an abstract setting.

Methodology

Setting and Participants

The study was conducted at an elementary school in suburban Maryland. The population of 95 sixth graders was diverse: 70% Caucasian, 28% African American, and 2% Asian. These students were in one of three mathematics classes with an average class size of 32. The ratio of males to females was 6:4 in two classes and 5:5 in the other. The unit of analysis included me

and 12 target students. Four target students were randomly selected from each of the three classes by the school counselor. The gender and racial backgrounds of the target students were as follows: 1 African American and 4 Caucasian females; 1 Asian, 2 African American, and 5 Caucasian males.

Participant Observation

As the mathematics teacher, it was feasible for me to conduct the research study in my own classroom. A 2-week pilot study was conducted in December 1996, and a 6-week formal study was conducted during the months of January and February 1997. As the teacher and participant-observer, I was involved in planning, setting up, and implementing the tasks as well as collecting the data.

Procedures

Three 2-week units were developed and presented to each mathematics class during the 6-week study. The students worked in groups of four and were switched to different small groups after each unit was taught. The students applied their mathematical knowledge to complete hands-on geometry investigations (Unit 1). The students integrated their knowledge about weather with mathematics in order to learn how to read a Celsius thermometer, graph data, and use hand-made instruments to find relative humidity and wind speed (Unit 2). The students also used abstract reasoning skills to solve 2 x 2 or 2 x 3 matrix problems using the operations of addition, subtraction or scalar multiplication. (Unit 3).

Each target student was videotaped three times—once during each unit. Only the cameraman and the counselor knew the participants' identities. When the study concluded, I received a list of the participants' names and the videotapes from the counselor and began to review the data. The types of participating behaviors were tallied by using a classroom

observation instrument and compared using a paired t test. A scoring rubric, developed after the pilot study, was used to judge the quality of student discourse. The discourse was rated as meager, moderate or elaborate.

All 12 of the target students were interviewed three times—once after each unit. The participants responded to a protocol of questions that was designed to obtain information about their levels of participation, attitudes, and task preferences. The counselor conducted the interviews and these data helped me to triangulate the data.

Data Sources

Teacher documents included a written journal, computerized field notes, sample units and lesson plans. Student documents included work samples, written journals, interview transcripts, and report cards. The primary data source was 36 episodes of videotape, which showed the participants performing 3 different activities—1 from each unit. All of the audiotapes and several videotapes were transcribed and analyzed to determine what patterns and themes emerged around the activities.

Results

To answer the first research question, both qualitative and quantitative research methods were used. The videotapes of classroom activities and the audiotapes of the target students' interviews were analyzed for patterns, and a paired t test was used to compare the target students' participating behaviors across the three task settings. After reviewing the videotaped episodes, five types of participating behavior appeared to emerge consistently as the target students interacted with their peers and me. The types of behavior were: 1) giving information; 2) asking or requesting information; 3) directing others; 4) helping others; and 5) agreeing or disagreeing with others. There was no significant difference in participating behavior across the

three tasks on the first four types of participating behavior. However, the amount of agreement and disagreement was statistically significant when a paired t test was used to compare the interactions that occurred in the abstract setting with the applied setting ($t = -4.93$, $p < .01$, two-tailed) and the integrated setting ($t = -5.49$, $p < .01$, two-tailed). Thus, one research finding is that the types of discourse varied slightly among the three task settings.

Each task setting provided the students with different opportunities to develop different ideas (Duckworth, 1996) and to solve unique mathematics problems. Moreover, the target students' interviews revealed that personal preferences influenced their participating behavior. As shown in Figure 1, each of three target students had the highest rate of information giving behavior in a different task setting: Amanda, Calvin and Philip gave the most information in the integrated setting (BV1T2), applied setting (BV1T1), and abstract setting (BV1T3), respectively. These target students' interviews show that personal preferences contributed to their level of participation. Amanda stated, "I like learning about the weather." Calvin said, "I liked constructing a building...." Philip claimed, "I liked the matrices...." These data suggest that curricula can and should vary with the needs, interests, and cultures of the students (Banks, 1991).

To answer the second research question, the videotapes were reviewed for patterns and themes. Several tapes were transcribed, and it was discovered that teacher behaviors influenced the amount and quality of student discourse. Four factors influenced the amount and quality of the student discourse: 1) teacher pedagogical content knowledge; 2) teacher questioning strategies; 3) use of instructional strategies; and 4) classroom norms. This suggests that it is teacher actions that encourage or restrict students' thinking. Thus, a second finding is the quality

of classroom discourse is less dependent on the activities and the task setting and more dependent on teacher variables.

The third research question emerged after to study was over. I realized that facilitating discourse and maintaining an equitable climate where all students were able to participate and offer explanations was not an easy task. As an African American female, I thought I was equitable in calling on students to participate in class. I often called on minority or female students at the outset, but the data show that I called on males more often in the abstract setting (see Table 1). As shown in Figure 1, low- and middle-achieving students had less participation than high-achieving students did in this context. This result is not surprising since students must focus on computation in abstract problem solving, and high-achieving students are usually better at computation.

I learned important lessons in facilitating student discourse by observing the videotapes and transcripts of data from the abstract setting. The data revealed how the students' thinking developed, how their level of participation increased and how I engaged them during a lesson on scalar multiplication of matrices. The matrix problem the students were presented with and the discussion that emerged are shown below. Pseudonyms are used for anonymity.

Text 1, Abstract Setting (Class 3)

$$3 \begin{vmatrix} 6 & 9 \\ 0 & 1 \end{vmatrix} =$$

Kate and the teacher

1	Teacher:	And I've got something a little different on the board. I wonder
2		if you can figure it out. Put something down [on paper] in the
3		answer matrix, and see if you are reading my mind.
4		Can you read my mind today?

5	Teacher:	All right. I'm looking for someone that will take a risk, someone
6		that will take a risk and give me an answer that they think makes
7		sense. Hands down, though, because I am looking for the fastest
8		hand that can give me an idea. We value ideas in this class!
9		All right. Let's hear from Kate. What do you think?
10	Kate:	The answer for the top is . . . top left is . . .
11	Teacher:	First row, first column?
12	Kate:	Yeah, 9.
13	Teacher:	Explain why you think that?
14	Kate:	Because there's a 3 on the outside of the box and then 6.
15		You add them and get 9.
16	Teacher:	Okay. How many like that system?
17	Class:	[Some raise hands.]
18	Teacher:	I like that system!

Learning from my interaction with Kate

The criteria used to judge the complexity of the mathematical discourse in the abstract setting was the students' ability to develop a mathematical proof or argument. The continuum ranged from meager complexity to elaborate complexity. At first glance, it appeared that Kate's mathematical discussion with me was of moderate complexity. She gave a typical response since the class had been working on addition of matrices for the past two days. Yet, she tried to explain or justify her answer with a "because" statement in Line 14. The word "because," a subordinating conjunction, implies a relationship between two ideas (Longo, 1993). Kate's response was mathematical correct, but her explanation was not as detailed I wanted it be. I tried

to put the words, "first row, first column," in her mouth. Had she used those matrix vocabulary words instead of "top left" I would rated the quality of her discourse closer to elaborate. Thus, I learned that teacher judgments are based in part on teacher expectations. Because Kate did not say what I wanted to hear, her discourse was rated a moderate.

Text 2, Abstract Setting (Class 3)

David and the teacher

1	Teacher:	Who can think again and tell me another way to get something
2		different? David?
3	David:	Um. The answer is 729.
4	Teacher:	I'll put 729 there (in the answer matrix).
5	David:	Because . . . uh . . . it's 3^6 . . . is 729.
6	Teacher:	Did we . . . ? Wait a minute. Could you repeat that?
7	David:	Okay. You have a 3 outside the matrix box so the 6 must be the
8		power. So 3^6 is 729.
9	Teacher:	Is it? How many people think that it is 729 . . . I mean 3^6?
10	Class:	[Shows nonverbal agreement/disagreement signals]

Learning from my interaction with David

The discourse that David had with me was characterized as elaborate in complexity because his explanation was unconventional and unexpected. It had been several weeks since the class had studied exponents. David was able to reach back and pull from his previous knowledge. He presented what I thought was a sophisticated solution since his answer could not be found by using basic operations. David used "because" to explain his reasoning, and he did so without being asked to explain. He also used the word "so" which functioned like "because" to

indicate a logical relationship (Longo, 1993). I believed his response was elaborate because he provided the class with an explanation, and he used mathematical reasoning to argue his position by claiming, "... so 6 must be the power."

Like Kate, David's mathematics was accurate since "3^6 ... is 729." However, neither of them gave the correct response, which was eighteen. However, the rating I gave students was different because I attempted to place a value on their responses. The purpose of the activity was to elicit different ideas from students. Both responses served that purpose and, as shown in Text 3, helped the class to get excited about the mathematics.

Text 3, Abstract Setting (Class 3)

The class and the teacher

1	Teacher:	Who could prove it by telling me 3^1, 3^2, 3^3 ...?
2		Who has one power?
3		[Coaxing.] Come on. Stephanie, which one?
4	Stephanie:	Three to the first power.
5	Teacher:	You want 3^5?
6	Stephanie:	Three to the first power.
7	Teacher:	Oh, first power! Okay.
8	Stephanie:	Three.
9	Teacher:	Okay. That was easy. You call on somebody, Stephanie.
10	Stephanie:	Nancy.
11	Nancy:	Um, 3^2 is 9.
12	Teacher:	I'll take it, and anyone else that wants to fill in something. You
13		call on someone, Nancy. Two seconds.

14	Nancy:	Burton.
15	Burton:	Three to the third power . . . 27.
16	Teacher:	I'll take it, but nobody knows 3^4. That's too hard. [Hands go up.]
17		You know it already without multiplying it. Golly! I
18		don't believe it! Earl, I don't believe this!
19	Earl:	Sixty-four.
20	Teacher:	I'll put it.
21	Mary:	Un-Un.
22	Philip:	No, . . . wrong.
23	Teacher:	Earl, call on someone to help you out, quickly.
24	Class:	Earl, Earl!
25	Earl:	Bill.
26	Bill:	It's 41.
27	Class:	No. No.
28	Philip:	Eighty-one. [thinking out loud]
29	Mary:	Eighteen.
30	Keith:	Eighty-one.
31	Teacher:	Before we go on somebody tell Earl what the factor form is.
32		What would be the factor form, Susan?
33	Keith:	Oh, I know!
34	Susan:	Uh, 27 x 27 x 27.
35	Keith:	It's 81.
36	Philip:	It's plus.

37	Teacher:	Call on someone, Susan.
38	Class:	Susan!
39	Susan:	Jenny.
40	Jenny:	Twenty-seven times 3 is 81.
41	Teacher:	How did you get it?
42	Jenny:	I added it.
43	Teacher:	You added what? How many times?
44	Jenny:	I added 27 three times.
45	Teacher:	All right, 3^5, you had time. What's your answer, David?
46	David:	Uh, 243.
47	Teacher:	Now 243 times 3. Who knows that easy problem?
48		I know you know it. And what do you say, Ted?
49	Ted:	Seven-twenty-nine . . . 729.
50	Teacher:	Excellent, and that's the first time, I heard your voice all year.
51		But guess what? That's not the system I'm using.
52	Class:	Oh!

Learning from the Students' Thinking Processes

The controversy that developed over the value of 3^4 generated a lot of discussion in this class. Many students wanted to share their ideas with the class. By facilitating discourse, I became aware of the knowledge as well as the errors and misconceptions the students had.

Earl, an articulate student, often asked intriguing questions in mathematics class. He said the answer to 3^4 was 64 (Line 19). Although this answer was incorrect, Earl knew that he needed

to multiply a string of numbers together to get his answer. He correctly multiplied 4 x 4 x 4 to get 64, but reversed the process by multiplying exponents together instead of bases.

Bill's answer of 41 (Line 26) revealed that he knew how to follow the pattern in the chart to solve the problem. He had to multiply the answer to 27 by 3. However, his answer showed that he had difficulty with the multiplication algorithm. When he multiplied 27 x 3, Bill multiplied the ones (7 x 3) to get 21. He wrote the one and carried the two. Then he multiplied the 2 he carried by the 2 tens in 27 to get 40, making a common error.

Mary maintained a high level of participation in this matrix lesson. Her answer of 18 (Line 29) revealed that she could use the correct factor form—3 x 3 x 3 x 3—to solve 3^4. However, the problem Mary actually solved was 3 x 3 + 3 x 3. Her mistake was adding 9 + 9 instead of multiplying 9 x 9. Like Earl, Mary understood the process, but she made an error when she used the wrong operation in the final step.

Susan demonstrated her knowledge about factor forms. Susan knew that she had to use 27 and 3 to get the answer to 3^4. She reasoned incorrectly that the factor form was 27 x 27 x 27. Ironically, she was able to get the correct answer of 81 because she added 27 + 27 + 27. String multiplication was exactly the same as string addition in Susan's mind. Thus, it is important for students to share their solution strategies because it is possible for students to have the right answer but arrive at it by a faculty thinking process.

These four students demonstrated that they had some understanding of advanced mathematical concepts. With some reteaching, all of them could have the tools needed to solve problems with exponents. When opportunities are presented for students to articulate their thinking skills, teachers become more aware of students' strengths and limitations.

Discussion

Genuine student contributions are uncommon in most classroom discussions because the cycle of teacher initiation, reply and evaluation (IRE) is hard to break (Cazden, 1988). When social norms are relaxed, the IRE form of classroom discourse can take the emergent form when students begin to make call outs and choral responses (Longo, 1993). As shown in Text 3, emergent discourse can generate a great deal of excitement. It is important for teachers to facilitate both institutionalized (IRE) and emergent forms of classroom discourse in order to provide students with verbal cues and opportunities to make spontaneous responses.

Teacher behaviors influence the social context and determine if students will feel comfortable enough to participate. The decision to explore exponents raised the level of student involvement in this study because the students saw a more familiar mathematical representation. By taking the focus off of the matrix problem for a moment, more students were eager to take risks. As a result, the social norms were relaxed, creating a climate for more students to be drawn into the discussion. Students were able to scaffold by building upon other students' answers. Thus, teachers control the discourse by knowing when to give information, when to clarify, when to model, when to lead, and when to let the students struggle to construct and understand important concepts (Ball, 1993).

Research shows that the social context and teacher behaviors perpetuate inequities in classrooms (Ambrose, Levi, & Fennema, 1997; Campbell, 1995). While the rate of male and female participation in this study was not significantly different, the data do show that teacher expectations influence the participation levels of females and minority students. Teachers must do more than call on males and females and whites and blacks proportionately. Teachers must

understand that girls and minorities have different learning styles and have high expectations for everyone.

This research study shows when students are given variety of tasks in different task settings, participation is high and students are able to generate "wonderful" mathematical ideas (Duckworth, 1996). Applied and integrated tasks allow girls to "do" mathematics and use "connected knowledge" to make conjectures, generalizations and use inductive thinking (Campbell, 1995; Jacobs & Becker, 1997). As show in Figure 1, Amanda made no statements during the scalar matrix lesson, but she did verbally participate in the applied and integrated settings. This data supports the claim that females have a preference for hands-on tasks. The amount of student interaction in the classroom is a strong predictor of academic success (Cohen & Lotan, 1995). Thus, it is imperative that teachers use a variety of tasks in order to engage all students at high levels.

As a result of my inquiry and reflection, I became more sensitive to gender issues, sought additional information about gender and mathematics equity and developed strategies to engage more females in classroom discussions. This type of research is significant because it impacts educational practice and contributes to the field of teacher-research. Teacher-research offers practitioners the chance to view their instructional practices objectively and to become proactive in changing their pedagogy. The *Standards* call for inequities to be redressed by creating a forum for *all* students to engage in mathematical discourse. Classroom discourse encourages reflective and personal thinking on the part of both students and teachers. Teachers cannot expect their pedagogy to change overnight; reform is an on-going process. However, teachers can be pragmatic and strive to improve their teaching techniques one lesson at a time.

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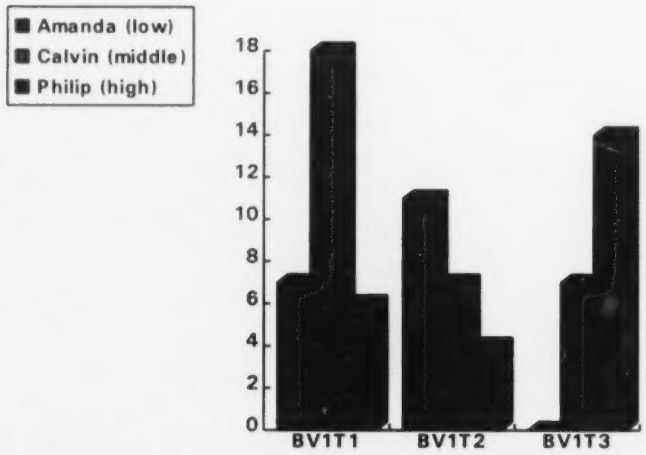

Figure 1. Bar graph of the frequencies of three target students' participating behaviors by achievement across task environments.

Note. Frequencies were recorded at 1-minute intervals for a 25-minute duration. BV1T1 is behavior 1 (giving information) in Tasking Setting 1; BV1T2 is behavior 1 in Task Setting 2; BV1T3 is behavior 1 in Tasking Setting 3.

Table 1

Student Participation by Race and Gender in the Abstract Task Setting (N=95)

	Class 1 (n=31)		Class 2 (n=31)		Class 3 (n=33)	
	Females (n=13)	Males (n=18)	Females (n=15)	Males (n=16)	Females (n=13)	Males (n=20)
Whites (n=66)	5	10	7	9	5	10
Percent (70%)	56%	71%	77%	90%	71%	63%
Blacks (n=27)	3	3	5	4	3	2
Percent (28%)	75%	75%	83%	80%*	50%	100%
Asian (n=2)	---	---	---	---	---	2
Percent (2%)						100%
Total Participants	8	13	12	13	8	14
Percent (100%)	62%	72%	80%	87%	62%	70%

Note: 1 Black male was absent from Class 2 the day the data was collected; percentages are adjusted.